ERGOTEC ASSOCIATION, INC.

Human Engineering Non-Profit

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93-62

William Caton, Secretary
FCC
1919 M Street, NW, #200
Washington, DC. 20554

September 3, 1996

BY HAND

Re: Report and Order -- FCC 96-326 - Petition for Reconsideration

Dear Mr. Caton:

Enclosed are three documents on the bio-effects of electromagnetic radiation (EMR). Please file under the above Report and Order. (1) *Soviet Research on the Neural Effects of Microwaves*, which might have given rise to the ANSI limit of 10 mW/cm2 (page 26). (2) Pages from my book **X-Rayed Without Consent** discussing the irradiation of personnel at the US Embassy in Moscow. They were exposed to 1-15 uW/cm2, and suffered irreparable injury and death. (3) The findings of Chiang Huai, *Assessment of Health Hazard and Standard Promulgation in China*, that were presented to NATO before the Persian Gulf War. Huai also notes the bio-physiological damage in State Department personnel exposed to 1-15 uW/cm2. The human injuries highlighted in these documents deal with both thermal and non-thermal disorders.

EMR exposure limit recommended by the health and safety Interagency Group to FCC will be 1 mW/cm2. The ANSI specific absorption rate (SAR) to airborne radiation is 1.8 W/kg of tissue. Now FDA says PCS users can absorb up to 1.6 W/kg. Touching PCS phones (contact electricity), which operate at high gigahertz (GHz) frequencies whereas cellular phones function in the lower megahertz range, will induce high SARs and strong electric currents in the body for longer periods.

What will be the joint effect when EMR is absorbed directly (contact) as well as from airborne sources impinging on the biologic system? This is a major concern in view of the fact that *many carriers* will install ***many antennas*** **all over the country**.

It is not expected the Commissioners nor anyone will react to the foregoing caveat. But Ergotec along with many citizens groups nationwide goes on record to state, **"The biological and environmental outcome of ubiquitous radiation from many sources in our ecosystesm will be destructive to humanity and the US economy."**

Sincerely,

Bert Dumpé

cc: Commissioners, Interagency Group

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ET

Enclosed (New York objection to PCS antennas by Arthur Firstenberg.
This is representative of citizen opposition nationwide and worldwide.)

SOVIET RESEARCH ON THE NEURAL

EFFECTS OF MICROWAVES

Report 66-133

7 November 1966

Surveys of Foreign Scientific and Technical Literature

SOVIET RESEARCH ON THE NEURAL EFFECTS OF MICROWAVES

ATD Work Assignment No. 79-67-1

Aerospace Technology Division
Library of Congress

INTRODUCTION

The primary purpose of this report is to outline Soviet research on the effect of low-intensity microwave radiation on the central nervous system of living organisms, including man. The material presented here has been drawn exclusively from open-source technical literature, covering in the main, the period of the last decade. The report consists of several sections which may be read independently.

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1. Scope of effort: organization and individual researchers

Open source literature, especially that of the last ten years, indicates that there has been a lively and sustained Soviet interest in the interaction between high-frequency electromagnetic radiation and biological systems. To the extent to which such literature reflects actual research efforts, it must be assumed that Soviet work in this field is extensive and involves a large number of scientific personnel who are pursuing a wide range of specialized research goals. While this interest extends through the range of typical problems, such as those dealing with industrial hygiene and microwave therapy, the subject attracting the greatest attention in this field is the "unknown" or nonthermal effects of microwaves. A number of studies have dealt with this effect.

Serious interest in a given field of scientific study is usually manifested by the involvement of several institutions which normally assume the leading role in the research and pursue it in a systematic manner. There is also the usual background of less directly involved organizations and individuals who publish in a somewhat less systematic manner, sometimes perhaps as the by-product of other research, but who are always present in the aggregate and add their voice to the discussion in proportion to the significance generally ascribed to the subject. All these elements are quite evidently present in this case.

Two organizations in the USSR appear to have taken the lead in systematic research on microwave interaction with biological structures: the Central Scientific Research Institute of Health Resort Science and Physiotherapy, and the Institute of Industrial Hygiene and Occupational Diseases of the Academy of Medical Sciences USSR, both located in Moscow. The names of these organizations, however, do not preclude their interest in this field from reaching far beyond the problems of microwave therapy and the protection of workers exposed to high-intensity fields.

A. S. Presman, of the Central Scientific Institute of Health Resort Science and Physiotherapy, is the most important researcher working in the area of the effect of microwaves on living organisms. In addition to his research work, Presman is a leading interpreter of this subject and is the author of several comprehensive reviews of Soviet and non-Soviet achievements in this field. During the period 1955—1958, Presman worked in the aforementioned Institute of Industrial Hygiene and Occupational Diseases, where his research dealt with problems of industrial protection against exposure to microwaves. However, sometime around 1960, Presman began writing under the byline of his present affiliation and, simultaneously, his area of interest shifted to low-intensity microwave effects, mainly concerning the central nervous system. (Emphasis on low-intensity microwave effects seems to be characteristic of the work of the Institute of Health Resort Science and Physiotherapy as a whole). A small proportion of Presman's work concerns microwave therapy.

Presman is the apparent leader of a team of workers of the Institute, consisting of Yu. I. Kamenskiy, N. A. Levitina, S. M. Rappaport, and L. A. Blyumenfel'd, who are responsible for a considerable number of research reports published in the period 1960—1965.

The byline of the Central Scientific Institute of Health Resort Science and Physiotherapy has appeared in reports on the biological action of microwaves by other authors, who may or may not be associated with Presman. Included in this group are F. L. Leytes, L. A. Skinrikhina, A. N. Obrosov, and A. Krotov, who have written a number of papers on microwave therapy.

The Institute of Industrial Hygiene and Occupational Diseases seems to have a somewhat larger group of researchers engaged in work on microwave effects. This institute's principal researchers on low-intensity microwave effects also continue to contribute reports on industrial protection against microwaves. A fairly cohesive group consisting of Z. V. Gordon, Ye. A. Lobanova, M. S. Tolgskaya, S. F. Belova, I. A. Kitsovskaya, A. A. Letavet, K. G. Knorre, B. M. Belitskiy, and S. V. Nikogosyan has been publishing steadily since 1955, mainly on experiments concerning microwave irradiation of animals. Much of the output of this group centers around the publication in 1960 of the Institute's proceedings on the biological action of ultrahigh frequencies. Although the output of the Institute of Industrial Hygiene and Occupational Diseases has fallen off somewhat during the last two years. There is some evidence that renewed activity may be contemplated.

A number of local institutes of industrial hygiene and occupational diseases not under the jurisdiction of the Academy of Medical Sciences, but under the various republic ministries of health are active in microwave research. Included are the Leningrad Institute of Industrial Hygiene and Occupational Diseases, and its Georgian, Ukrainian, and Gor'kiy namesakes. All of these institutes have published research reports during the last decade dealing with Industrial protection against microwaves.

In spite of the diminished output of the Institute of Industrial Hygiene and Occupational Diseases over the last two years, overall Soviet research and publishing activity on the biological action of microwaves have by no means lessened. The type of research characteristic of the Gordon group was taken up in 1964 by an organization new to the scene, the Bogomolets Institute of Physiology of the Ukrainian Academy of Sciences in Kiev. The individual researchers at the Bogomolets Institute, E. L. Revutskiy, K. M. Solovtsova, S. F. Gorodetskaya, N. I. Kerova, V. S. Belokrinitskiy, and M. I. Yatsenko, were also new to the scene. The work of the Bogomolets Institute is divided between the Department of Clinical Physiology and the Biophysical Laboratory. The output of this organization has been quite steady from 1964 to the present.

A small but interesting microwave research team is associated with Yu. A. Kholodov, of the Institute of Higher Nervous Activity and Neurophysiology of the Academy of Sciences USSR in Moscow. The group, besides Kholodov, includes Z. A. Yanson and A. L. Eldarov. Since 1962, Kholodov has been engaged in experimental studies of of the effect of microwaves on the central nervous system of animals, and should be regarded as one of the most significant personalities in this field. Parallel with his microwave studies, Kholodov has worked with the effects of magnetic fields on biological systems including the central nervous system. His reports in this area date from 1958.

V. R. Faytel'berg-Blank, of the Ukrainian State Research Institute of Health Resort Science and Physiotherapy, is working on the effect of microwaves on the gastrointestinal tract.

In addition to the systematic research carried out by the several institutes described above, which clearly appear to have been charged with the major responsibility of developing microwave research, other, isolated, research papers, both with and without by-line, have appeared regularly during the last decade. These papers have covered a wide range of studies from low-level microwave effects to industrial hygiene and microwave therapy. Particularly interesting is a work by N. N. Livshits, of the Institute of Biological

Physics of the Academy of Sciences USSR, published in 1957—1958 on the effect of microwaves on the central nervous system. Other significant papers are by R. A. Chisbenkova, of the Institute of Higher Nervous Activity, on the effect of AC magnetic fields on rabbits, F. P. Petrov of the Laboratory of General Neuro-Muscular Physiology, on the effect of low-frequency electromagnetic fields on higher nervous activity, V. A. Pukhov, of the Kirov Military Academy, on microwave effects on the central nervous system, etc. In this group of papers with random or no institutional affiliation, each author has contributed very few articles on the subject during the past decade. The relatively large number of such papers, however, is not without significance: it is a fairly reliable indication of the widespread interest in the problems of biological effects of microwaves that apparently exists in the Soviet Union.

Several conferences have been held in the USSR on the biological effects of microwaves. The first such conference dealt with the application of short and ultrashort waves in Medicine, and was held in Moscow in 1940. Several conferences on the application of radioelectronics in biology and medicine and on industrial hygiene and the biological action of radiofrequency electromagnetic waves were held between 1957 and 1962. Unfortunately, no proceedings of these conferences are available.

Since much of the earlier Soviet material on this subject has been treated by the writer in other ATD reports*, and since very recent material reflects the history of Soviet research and development in this area, the present report will concentrate primarily on material published in the 1964—1966 period. As an index of present Soviet activity in this area one of the articles cited in this report appeared as recently as 10 October 1966.

Special emphasis will be placed on the neural (especially nonthermal) effects of EMF's, particularly in the microwave range, although some attention will also be paid to electric, magnetic, and low-frequency electromagnetic fields. Following a review of Soviet research concerning the effects of EMF's on specific neural functions and structures, this report will discuss the results of Soviet experiments on animals, the clinical and hygienic aspects of human exposure to EMF's, and finally, a summary and discussion of the ramifications of the Soviet research effort in this area.

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*Dodge, C. H. Biological and medical aspects of microwaves. ATD *Foreign Science Bulletin*, v. 1, no. 2, 1965, 7-19.

__________ The biological effects of electromagnetic fields (annotated bibliography). ATD Report P-65-17, 1 April 1965, 44 p.

__________ Biomedical microwave research (compilation of abstracts). ATD Press (Special Issue), v. 4, no. 43, 1965, 10 p.

__________ Biological effects of microwaves (compilation of abstracts). ATD Report P-65-68, 17 September 1965, 93 p.

3. Specific neural functions and structures

This section will treat those research efforts devoted to revealing specific effects of EMF's in the microwave range on the functions and morphology of various neural and neuromuscular structures. In this area, *in vitro* experiments are of particular interest because they necessitate an intimate knowledge of biophysical principles and therefore, rigid control of all physical and biological parameters, accurate dosimetry, and maximum viability of the structure under consideration. Because of these obstacles, relatively few Soviet studies have dealt with this aspect of EMF effects.

On the other hand, a considerable number of papers in the last decade have reported neural cytomorphological results of exposure to microwave-range radiation. Here, both locally and totally irradiated animals have been investigated. The findings of these studies have been fairly consistent. Tolgskaya et al. [4] compared the effects of thermal and nonthermal 10-cm waves on various organs of whole-body-irradiated rats. Exposure to thermal, 40—110 mw/cm^2 fields resulted in vascular damage to all internal organs, including the nervous system. Damage to the latter was characterized by pericellular and perivascular edema, both massive and minute cerebral hemorrhaging, and vacuolization and protoplasmic swelling of brain cells.

In animals exposed to a slightly thermal, 19—31 mw/cm^2 field of the same wavelength for 30 min, the following similar changes were noted: Perivascular and pericellular edema and hemorrhaging of neural structures, severe protoplasmic swelling of parenchymatous nerve cells, and significant cerebral microglial activity.

Of particular interest in this study were results of exposing animals to nonthermal intensities of 10-cm waves for 30 min. Animals exposed to 7.0—9.5 mw/cm^2 and killed immediately thereafter showed more pronounced vascular reactions in neural structures than in any other organ. A cerebral microglial reaction was interpreted as an indication that the brain is the first structure to exhibit a mesenchymal reaction to centimeter waves. Those authors concluded that while the severity of pathological shifts is generally a function of field intensity and exposure duration, the thalamus and hypothalamus appear to be the most sensitive structures to centimeter waves. Although the authors did not speculate on the functional ramifications of these effects, the study supports the opinions of other prominent Soviet theoreticians (Livshits [1,2], Presman [5,6], and Osipov [32]) that neural structures respond to microwave field intensities which do not result in a significant increase in body temperature.

The year after the study mentioned above [4], Lobanova [7] (a participant in the Tolgskaya study) further investigated the effects of a nonthermal, 10 mw/cm^2 intensity of 10-cm waves on the cytomorphology of interneuron connections. She did not specify exposure duration other than to say that it was "prolonged" and that the animals were multiply exposed. A reasonable guess of the duration of exposure would be 30 min, based on the previously mentioned study.

Using the Golgi-Bubanet method, the author revealed that the fine projections of dendrites were in the process of disappearing and, in some cases, showed thickening or swelling. Apical dendrites leading to the upper layers of the cerebral cortex were the most noticeably affected. As the number of exposures to microwaves increased, the process of dendrite formation extended deeper into the cortex toward the nerve cell itself. Lobanova theorized that these structures may be specific receptors of microwaves, although she was cautious enough to mention that these structures had shown similar reactions to aniline and lead. In general, she concluded that changes in the higher nervous activity of animals exposed to microwaves were a function of interneuron disruption and that the effects of 10 cm (10 mw/cm^2) waves were basically nonthermal.

Another approach to determining the effects of EMF's on isolated neural structures involves the investigation of the bioelectrical activity of an *in vitro* or *in vivo* specimen under normal and experimental conditions. This approach is obviously complicated by the fact that rigidly controlled conditions are an absolute necessity, especially for *in vitro* specimens. Here, statistically reliable results are possible only if the parameters of irradiation can be accurately dosed and monitored. To this end, Presman and Kamenskiy [8] designed and constructed systems for irradiating neural or neuromuscular preparations, as shown in Figs. 1 and 2.

Kamenskiy [11] further refined these systems for research on specific neural preparations to provide for improved thermal control and shielding.

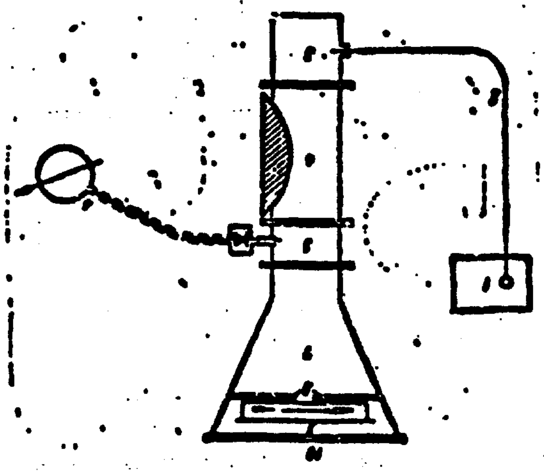

Fig. 1. Basic diagram for irradiating a neuromuscular preparation with 10-cm microwaves by dosing the power flux density

1 - Microwave generator; 2 and 3 - cable and waveguide; 4 - attenuator; 5 - power indicator; 6 - microammeter; 7 - horn; 8 - absorption plates; 9 - neuromuscular preparation; 10 - final screening absorption plate.

Fig. 2 is a variant of the device shown in Fig. 1.

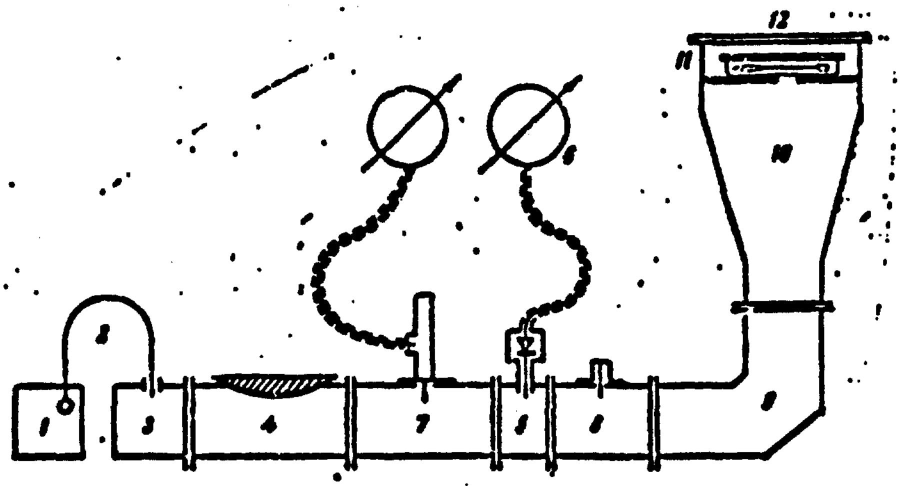

Fig. 2. Device for irradiating neuromuscular preparations with measured doses of microwave power

1 - Microwave generator; 2 - cable; 3 - waveguide pickup; 4 - attenuator; 5 - power indicator; 6 - microammeter; 7 - measuring segment; 8 - impedance transformer; 9 - bent waveguide; 10 - horn; 11 - radiation chamber; 12 - final screening absorption plate.

More recently (Kul'vanovskiy et al. [9]), there is evidence that still further refinement of the techniques for studying the bioelectrical activity of neural specimens is taking place (see Fig. 3). This F-shaped wet chamber consists of a thin, glass housing the size of which can be adjusted to conform to individual experimental conditions and problems. The main feature of such a

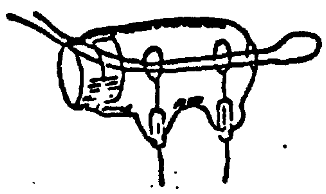

Fig. 3. Wet chamber for studying the bioelectrical activity of neural specimens

chamber is the freedom of recording nerve biopotentials under virtually normal, *in vivo* conditions. In their experiments, the authors used wet chambers with the following dimensions: 5-mm glass tubing 15 mm long with 2-mm projections for the insertion of platinum electrodes. The electrodes are tightly fixed in the orifices of the F-projections and are looped at the ends. The loops are 2 mm in diameter and the distance between electrodes is 5 mm. These simply constructed chambers guarantee constant electrical contact with the nerve and may be placed among the organs and tissues containing neural specimens. Since damage to the specimen can be avoided through the use of wet chambers, and since temperature and humidity integrity are assured by the surrounding organs or tissues, the prolonged viability of neural structures is possible. While the application of such a system in microwave research is not mentioned, it seems likely that the principle could find application here if the appropriate housing materials were used.

As earlier stated, relatively few definitive *in vivo* and especially *in vitro* investigations on the neural effects of EMF's have been reported by the Soviets. Kholodov [10] studied the effects of UHF (1000 v/m) on neuronally isolated sections of the cerebrum and midbrain of rabbits. Exposure duration was 2—3 min with 20—40-min intervals between exposures. Kholodov compared his results with the bioelectrical activity of intact brains and found that the latent period of the reaction of a neuronally isolated cortical specimen to UHF was 27 sec, as opposed to 53 sec for an intact brain. The UHF aftereffect duration for the former was shorter (1—5 min) than for the latter (15—20 min). Kholodov did not speculate whether these effects were of a thermal or nonthermal nature and this could not be ascertained from the irradiation parameters described. However, the results of this study are consistent with other, parallel investigations which have shown neural excitation to be characteristic of the response to microwave-range EMF's.

Perhaps the best controlled and most definitive research on the effects of microwaves on specific neural functions is reflected in a report by Yu. I. Kamenskiy [11], who studied the functional state of the frog nerve *n. ischiadicus*, during exposure to pulsed and continuous 10—12.5-cm waves (1—11 mw/cm^2). In this study, he first determined the thermal parameters of the microwave regimens used and selected an intensity of 11 mw/cm^2, which was sufficient to increase the temperature of the neural specimen by 1°C after an exposure of 20—30 min. The effects of continuous microwaves (12.5 cm, 11 mw/cm^2, exposure duration 20 min) were studied in the first series. In 34 tests, no reliable changes in threshold sensitivity were noted. The author did note, however, increased conduction rate, abbreviated absolute and relative refractory phases, and altered action current amplitude, which he judged to be of a thermal nature.

Most interesting were his tests with pulsed microwaves (10 cm, 1 msec pulse, 700 pulses/sec, exposure duration 20—30 min). Here, a definite increase in neural conduction and excitability was observed and was judged to be a result of the nonthermal (specific) effect. His reason for this conclusion was that at a frequency of 700 pulses/sec (pulse interval 1.4 msec) there was a summation of neural shifts. The pulsed intensity of radiation here was 1400 times greater than the mean level of intensity during continuous irradiation. Also, at frequencies of 100 and 200 pulses/sec, the pulse interval (5—10 msec) was too great to result in summation. Finally, the 0.2°C increase observed in specimen temperature during pulsed irradiation could not explain the five- to tenfold increment in conduction rate over values obtained when specimens were physically heated. Thus, definite, recordable shifts in neural excitation were observed during pulsed 10-cm-wave irradiation which could not be observed during continuous irradiation. The results of this investigation support the widely held Soviet view that pulsed microwaves are more biologically active in the neural sense than continuous (nonpulsed) microwaves.

Curiously, there is no evidence that Kamenskiy has continued research along these lines since 1964. However, another approach which has recently received more attention is being pursued by Presman [12], with whom Kamenskiy has collaborated in the past [8].

In [12] Presman studied the effects of pulsed and continuous 0—12.5-cm waves on the so-called excitable system of paramecia as possible approach to revealing the nonthermal mechanisms of microave effects on higher neural structures. He had previously demontrated that paramecia, when exposed to a-c and d-c currents, exibited an "electric shock reaction" (ESR) at certain threshold doses. n this study, he exposed paramecia located in a polystyrene chamber illed with a hay infusion and attached to the microwave generator to ontinuous, 12.5-cm waves in doses of one per second (dose duration —100 msec). This parameter resulted in a reaction similar to the SR. A second series was exposed to pulsed (200—700 pulses/sec) 0-cm waves with 7—50 msec durations once per second. This parameter revealed that the mean power threshold values for pulsed microaves were higher than for continuous microwave values. As in amenskiy's study with the frog nerve [11], a cumulative effect was haracteristic of the pulsed 10-cm waves. It is interesting to note hat Presman used the same parameters Kamenskiy used in his experients. Since both these researchers collaborated in the design of quipment for these neurally oriented studies, it is entirely possible hat they both used the same hardware.

Presman's third and fourth series of investigation were designed o ascertain whether microwaves sensitized paramecia to electrical currents. It was found that microwaves decreased the threshold voltage ecessary to evoke an ESR. The author interpreted these results, together with the fact that heating did not exceed 1.5°C in any series, o indicate the nonthermal effect of microwaves. His arguments against thermal explanation of the mechanism of the observed microwave effects ere as follows: 1) excitation threshold values for pulsed and coninuous microwaves were a function of the quadratic root of their dose uration or series; and 2) virtually no relationship between pulsed hreshold power and frequency was noted. Presman was satisfied that his approach and the data obtained in this study would help to clarify he mechanism of microwave effects on the "excitable" (neural) structures of higher animals.

Presman's results have closely paralleled Kamenskiy's, despite he difference in the specimens studied. Since Presman and Kamenskiy ere (or still are) collaborators, the same approaches to the problems of neural reactions to microwaves have been employed. All of the studies treated in this section, including Presman's and Kamenskiy's, strongly favor the theory that the mechanism of microwave effects on neural or neural-like structures is nonthermal, based on experiments in which threshold or nonthermal field intensities were investigated. Finally, while one might expect that the interesting results of the studies mentioned here would lead to an increased research effort in this area, there has been no recent perceptible increase in the number of articles devoted to this problem.

4. In vivo neural effects

A large complement of the Soviet research community devoted to the neural effects of microwave-range EMF's has used a more indirect approach to the problem. Here, the function or behavior of the whole organism or parts of it are studied during the action of various EMF irradiation parameters (local or whole-body irradiation). External, or functional patterns are deduced to reflect internal neural effects in the absence of any investigation of the neural structure itself. As regards the problem of classifying microwave neural effects as thermal or nonthermal, the results of many investigations are doubtful in this respect inasmuch as the biophysical, chemical, and even thermal parameters of alleged nonthermal effects have not been investigated. Another drawback of this indirect approach is the difficulty (if not absolute impossibility) of determining just how much microwave energy has reached the neural structures in question. This problem of comparative, *in vivo/in vitro* tissue dosimetry is of open concern to many Soviet researchers, Presman [5,6,13] in particular. The general consensus is that comprehensive research on this problem is absolutely necessary if the specific mechanisms of EMF effects are to be revealed. Nonetheless, the majority of Soviet researchers in this field feel that the behavioral and functional approach to studying EMF effects is a valid one in that it is possible to observe trends in biological responses to EMF's which clearly differ from responses to other, better understood stimuli. Therefore, this section will review some of the more recent works supporting this belief.

As far back as 1960, Presman [13] concluded that "Experimental studies in the Soviet Union and abroad have clearly indicated that, along with a thermal effect on the living organism, microwaves also have a so-called 'specific' effect" (a term that Presman coined himself). Functional shifts have been observed in the nervous and cardiovascular systems, as well as hematological and metabolic changes resulting from chronic exposure to 10—12-cm UHF at nonthermal intensities of 5—10 mw/cm². He was cautious enough to point out that, "The effective (medical) application of a specific effect of microwaves is possible only if the mechanisms of such an effect have been fully established."

It should be mentioned here that many different microwave research-oriented groups are active in this approach to revealing the behavioral and functional mechanisms of EMF effects. In fact, it is safe to say that hygienists (both military and civilian), physiologists, biologists, and theoreticians have at one time engaged in, or still are pursuing microwave research on animals and their various systems.

Gorodetskaya [14], representing the active Ukrainian group at the Bogomolets Institute of Physiology, studied the effects of SHF (3 cm, pulse frequency 577 cps, power density 0.4 w/cm^2) on the behavior of mice (and their progeny) situated 10 cm from the generator. To "eliminate" thermal effects, control animals were convection-heated in an incubator for 15 min until a temperature of 52°C had been attained. This temperature increase paralleled microwave-induced temperature increase. Gorodetskaya found that SHF had a more pronounced effect than heat on the genital organs, and therefore on the progeny of irradiated animals, and that female animals were more sensitive to SHF in this respect. Changes induced by convectional heat in hematopoietic organs were less severe than SHF-induced changes. Of interest relative to the neural effects of the wave range was the fact that the experimental animals exhibited more pronounced conditioned-reflex reactions in the form of negative responses than the controls. These reactions were found to be most pronounced immediately after the termination of irradiation. While convection-heated animals began to recover one day after exposure, SHF-irradiated animals did not begin to recover until the third or fourth day after exposure; recovery was virtually complete for control animals on the second day, while for SHF-irradiated animals, it took five days. Gorodetskaya therefore concluded that SHF has more pronounced effect than convection heat. The results of this study support the "specific" effect theory of Presman [5,6,13], and also support the widespread Soviet opinion that pulsed microwaves are very active biologically. Notwithstanding the fact that this was a "hot" (0.4 w/cm^2) experiment, neural and other responses were observed that could not be explained by a purely thermal effect. It is therefore possible that the nonthermal or specific effects of microwave EMF's can be observed even under highly thermal microwave conditions.

Another representative of this group, Faytel'berg-Blank [15] investigated the effects of 12.6-cm UHF (70 v for 10 min) on gastrointestinal glucose absorption processes of isolated preparations from dogs and rabbits. Unfortunately he did not describe the radiation parameters of the experiment in much detail. For instance, it could not be ascertained how far the preparations were located from the Luch-58 generator, what the power density of the field around the preparations was, whether pulsed or nonpulsed microwaves were used, what the thermal parameters of the specimens studied were, and therefore, whether the effects observed were of a thermal or nonthermal nature.

Innervated, partially denervated, and completely denervated specimens were investigated and the results were processed using a method of variation statistics. Faytel'berg-Blank found that a ten-minute exposure of the epigastral region to a 70-v, 12.6-cm wave field did not alter intestinal glucose absorption in a dog whose solar plexus had been eliminated. He concluded that sympathetic nerves, the solar plexus in particular, participate in the transmission of a microwave effect from the epigastral region to the intestinal region. The vagosympathetic system also plays a substantial role in this respect. When vagosympathetic nerves are blocked at neck level, the stimulating effect of UHF on resorption is impeded. When spinal ganglia are blocked, UHF slightly elevates the level of resorption but to a lesser degree than when the ganglia are intact. The role of skin receptors was also demonstrated. Thus, not only peripheral neural elements of the GI tract, but also central nervous mechanisms were observed to be responsible for transmitting UHF effects. However, since some shifts in resorption were observed even in denervated specimens, Faytel'berg-Blank proposed that humoral factors are also affected by UHF. In an attempt to further reveal UHF mechanisms, he studied cell respiration in the specimens and found that UHF caused a shift in this function also. He speculated that this might be a reflex response (UHF acting or controlling neural elements) or evidence of a direct UHF effect on the cells.

The results of Faytel'berg-Blank's study are difficult to interpret. However, the stimulatory effect of UHF on neural structures again was observed. This agrees with the results of most other investigations so oriented.

Another resorption study was conducted by Yatsenko [16], who investigated the effects of a 20-min exposure to 12.6-cm waves (40 w, no values for power flux density or the distance of the preparation from the 5—6-cm electrodes of the "Luch" generator given) on the absorption of radioactive phosphorus by knee-joint syncvial membranes. This function was studied in normal animals and those with severed spinal cords. Absorption activity was found to increase during the action of UHF. Spinal cord elimination alone retarded absorption, while under the effects of UHF, synovial absorption increased. Yatsenko felt that this was evidence of a direct UHF effect on synovial receptors and cited Faytel'berg-Blank [15] relative to the effects of UHF on peripheral nerves. Again, since no thermal parameters were mentioned in this study, it is unsafe to speculate that this study demonstrated the specific effect of UHF on central or peripheral neural function.

Semenov [17] better described the radiation parameters in an investigation of the thermodynamics of innervated and denervated femoral tissues in rabbits exposed to 12.6-cm waves (150—300 mw/cm^2, presumably a nonpulsed field, 10-min exposure duration, 3-, 4-, and 24-hr intervals between exposures). This was clearly a hot experiment and the author described in detail typical temperature-increase values for femoral tissue during irradiation. Semenov attributed a thermal cumulation or summation effect to neuroreflectory processes in the central nervous system. To test this hypothesis, he anesthetized animals and increased power density from 150 to 300 mw/cm^2 and found that the cumulative thermal effect was almost entirely precluded. He was therefore satisfied that sufficiently intense UHF fields are powerful stimulants which disrupt normal CNS adaptive processes, particularly tissue thermoregulation. Regrettably, he did not compare the effects of UHF with the effects of convection or local heating to add further strength to his conclusions. However, his study must be considered as further evidence that microwave EMF's affect CNS functions.

Using another approach to the problem of revealing microwave neural mechanisms, Pukhov [18] investigated the effects of neurotropic drugs (caffeine and medinal) on the viability of mice exposed to thermal (50 mw/cm^2), nonpulsed, 12.6-cm waves from a Luch-58 therapeutic generator. Exposure durations were 10 and 15 min, or the time necessary to kill the animals. Animals were irradiated 10 min, 60 min, and 24 hr following medinal injection and 60 min after caffeine injection. Pukhov found that caffeine, owing to its CNS stimulatory effect, statistically decreased the viability of irradiated animals, or, depending on the dose administered, resulted in no change. Medinal administered 24 hr prior to irradiation increased the viability of animals owing to its hypothermic effect. He could only conclude from this study that the mechanism of microwave effects on CNS functions requires further study. Here, the thermal (50 mw/cm^2) doses used would render difficult any concrete conclusion as to the specific effects of microwaves, especially nonpulsed waves, which Kamenskiy [11] and Presman [5,6] feel are basically thermal in their effect. However, this study would indicate that nonpulsed, thermal, 12.6-cm waves did hav an excitatory effect on the CNS.

In an interesting article by Malakhov [19], the effects of weak, nonthermal doses of UHF on conditioned reflexes were considered from the standpoint that such fields might play an important role in actually triggering reflexes. Malakhov feels that this problem is germane to the hypothesis that UHF, or microwave range fields, might act as "information carriers" of extrasensory signals (see the conclusions and discussion of this report).

To test this hypothesis, he attempted to develop conditioned reflexes to a 13.7-cm UHF field (20 mw/cm^2) in mice by using 20-sec conditioned (UHF) signals and 15-sec unconditioned signals. Responses were recorded oscillographically. The results of this experiment were disappointing in that reflexes to UHF, while demonstrable, were characterized by a long period of development, instability, a short residual effect, and rapid extinction. This same trend was observed by Kholodov [10], whose studies will be discussed in more detail in the next section. Malakhov could only conclude that weak UHF fields are of little "informative" (stimulatory) value to mammalian CNS patterns. He did state, however, that his results, while disappointing, deserved further investigation and that various animals (species not given) can serve as indicators (sensors) of microwave-range EMF's.

In a very recent article, Loshak [20] described an interesting experiment conducted to reveal the combined effects of pulsed UHF (1.0 mw/cm^2, other radiation parameters not given) and ionizing radiation (180-kv x-rays, 900-r whole-body dose) on white rats. Here, three groups of males were irradiated daily (2-hr exposure duration) 30 times. The first group was locally (head only) irradiated while the second group was whole-body-irradiated by UHF. The third group was used as a control and was irradiated by x-rays only.

The results of this study did not show preliminary microwave irradiation to have any protective effect, although Loshak, on the basis of other studies (not cited) had felt it might). He found, in fact, that pre-UHF exposure actually resulted in a more rapid mortality of x-ray-irradiated animals in both groups. The survival time for locally, pre-UHF irradiated animals was 17.1 $\pm$ 3.2 days, for whole-body-irradiated animals, 11.9 $\pm$ 1.0 days, and for control animals, 20.8 $\pm$ 2.1 days. Thus, decreased resistance to x-rays was the end product of nonthermal UHF exposure. Loshak attributed these results to the effects of UHF on hematopoietic structures, which in this study would imply that these organs are even more sensitive to decimeter-wave radiation than neural structures in view of the maximum mortality of whole-body-irradiated animals. Loshak stated that the lifespans of these animals indicated hematopoietic injury (especially of the bone marrow).

Unfortunately, Loshak's article appeared in abstract form, making it difficult for the reader to draw any concrete conclusions, especially those relative to the role of the CNS in this study. However, the fact that the group of locally (head only) irradiated animals also showed decreased resistance to x-rays is of interest. If, as Loshak stated, hematopoietic injury was responsible for decreased resistance to x-rays, an explanation is needed for the decreased (though not dramatically so, e.g., 17.1 ± 3.2 days vs. 20.8 ± 2.1 days) resistance of cerebrally irradiated animals. Above all, the fact that such a demonstrable biological effect was observed in response to such a low-intensity (1 mw/cm^2) decimeter-wave field is thought-provoking at the very least, since it would indicate a "specific" (nonthermal) biological effect of UHF. Loshak's observations also support the general Soviet opinion that pulsed microwaves are highly active in the biological sense.

5. Neural effects of low-frequency electromagnetic and magnetic fields

This section will briefly review some recent research on the neural effects of sub-microwave-range EMF's and constant magnetic fields. This area of research is of interest (with respect to magnetic fields in particular) because Kholodov [26,27], who is now active in magnetic field research, is also actively interested in research on the neural effects of microwave-range EMF's [10].

While research on low-frequency or very-low-frequency EMF's has been rather limited in scope and quantity, it is apparent from the research of Petrov [21] (1929), who initiated comprehensive research in this area, that Soviet interest in the biological effects of EMF's has had a long history. Petrov's last article in 1952 [22] demonstrated a weak and unstable reflex reaction to a low-frequency EMF. Since then, Sazonova's research [23,24] and Plekhanov's recent study [25] are the only indication of a continuation of Petrov's approach.

Sazonova [23] investigated the neural function of rabbits exposed to a 50-cps EMF generated by two 10-M transformers through 500-x 500-mm electrodes separated by 1200 mm. Each transformer generated a 65,000-v field. The *n. tibialis* nerve (*in vivo*) was studied using an ergographic setup which made it possible to load the paws of the animals with weights. Training prior to experimentation required one month. The field intensity ranged from 300—1000 v/cm. He found that these EMF parameters had a deleterious effect on motor function and that the effect of a 1000-v/cm field was more readily apparent than the effect of a 300—400-v/cm field.

In her second study [24], Sazonova continued to investigate the role played by the central nervous system in the motor activity of rabbits exposed to the same 50-cps EMF. Here, she used stimulatory and inhibitory neurotropic drugs (dibasol, novocain, aminazine) as a method of better revealing the neural mechanisms of the EMF effect. Animals were irradiated one hr daily, six days per week, for a month. In this study, a 100,000-v/m field was used. She found that inhibition of the reticular formation (tests with aminazine), or elimination of other neural pathways (novocain) delayed EMF-induced fatigue. Enhancement (dibasol) of CNS activity resulted in more rapid fatigue. Sazonova thus felt thatshe had demonstrated an EMF effect on the central nervous system relative to its participation in motor functions. It is interesting that the results of this study are similar to the results of some microwave experiments which indicate a stimulatory effect of EMF's on neural structures. Perhaps, as Osipov suggested in 1965 [32], a wide wave range of EMF's have a more or less analogous effect on the central nervous system.

More recently, Plekhanov [25] studied the effects of a low-frequency (735-kc) EMF on human conditioned reflexes to cold, using a plethysmographic technique which he felt was the best approach because of its sensitivity. A portable diathermy generator was used. He found that when field voltage was varied from 220—330 mv/m (110 mv/m variation), a conditioned reflex was noted which was attributable only to the variation in field voltage. He speculated that the mechanisms of the reception of this EMF range are to be found in the retina and skin receptors, the latter being specific EMF receptors. He concluded, however, that any living cells, especially neural cells of the brain, are EMF receptors, and that the mechanism of intracellular reception might be physical and chemical in nature. The possibility that EMF effects might be analogous to weak doses of ionizing radiation was not discounted. This would render the low-frequency EMF a nonspecific stimulus.

As to the effects of magnetic fields on "excitable" and neural structures, it is noteworthy that Yu. A. Kholodov [26,27], the leading Soviet spokesman for this research effort, has also been active in research on the neural effects of microwave-range EMF's [10]. In many respects, the approaches to investigating the neural mechanisms of magnetic field effects have paralleled the approaches to the microwave problem. Kogan et al. [28], like Presman [7], studied the behavior of paramecia in capillary tubes exposed to magnetic fields of 160—180 oe. Twenty to thirty time measurements were made before, 60—80 during, and 20—30 after the action of the magnetic fields. It was found that paramecia preferred the south pole of a magnet, that magnetic effects were gradual, and that these effects persisted after removal of the field. The effect of a magnetic field was found to be a function of its strength. Kogan did not use Presman's approach to this problem, in that he did not study the so-called electric shock reaction. He concluded that the magnetic effects he observed might be extracellular in nature (physical and chemical changes in the medium), and that this extracellular phenomenon might serve to explain the effects of magnetism on the functional state of organs and tissues. Kogan did not discount the possibility that magnetic fields might directly affect intracellular processes although he did not speculate on the possible mechanisms of such effects. Kogan did not cite Presman's study [7] nor did he discuss the so-called excitable system of paramecia.

Kholodov [26] reviewed the results of some of his investigations on fish, frogs, and rabbits exposed to intermittent (50-cps) magnetic fields ranging in intensity from 1 to 1000 oe (average, 100—300 oe). He found that pigeons did not develop conditioned reflexes to magnetic fields, while fish did. He felt that reflexes were affected by magnetic fields via the diencephalon or diencephalic structures (he also mentioned these structures as EMF receptors in his microwave research [10]. EEG's showed magnetic reactions by rabbit brains 53% of the time in intact animals and 63% of the time in neuronally isolated samples. His approach here was analogous to his 1964 microwave study and, interestingly enough, the results were similar in showing a magnetic field to be a direct stimulus of the central nervous system. However, the effects of other factors in this study should not be discounted since, as Kholodov pointed out, variable (50 cps) magnetic fields were used.

In the same investigation, Kholodov studied the impulse activity of 23 isolated cortical neurons. He could not detect any change in their background activity during exposure to his magnetic field parameters, but did note that their sensitivity to light increased during, and one min after the action of the field. While Kholodov was cautious in pointing out that the number of neurons studied was insufficient to draw any concrete conclusions, he mentioned that a morphological analysis of glial cells showed them to be highly sensitive to magnetic fields (he did not specify whether he meant constant or variable fields). He suggested that the biophysical mechanisms of magnetic field effects on neural structures might well be elucidated by tracing the chemical activity of glial cells, the trophic function of which is generally accepted. Kholodov plans further research on this approach.

It will be interesting to see how (if at all) Kholodov's magnetic field research affects trends in future microwave research in view of his active interest in the latter.

Recently, Chizhenkova [29], as if in response to Kholodov's research, investigated the EEG activity of rabbits with chronically implanted electrodes (sensorimotor area of the right cerebral hemisphere) exposed to 300-oe constant magnetic fields. Activity before, during, and after the action of the field was monitored using six animals in 604 tests. He observed a definite stimulatory effect of the magnetic field and showed that it was not a function of switching the field on or off. He would not speculate on which CNS structure was a specific receptor of EMF's, and suggested that his future efforts would be devoted to comparing magnetic effects with those of weak doses of ionizing radiation. This might imply that Chizhenkova is unsure whether magnetic fields have a specific effect on neural structures.

In his most recent communique, Kholodov [27] discussed the biological effects of magnetic fields in terms of space biology and medicine. He proposed the use of magnetic, antiradiation fields for spacecraft and also stated that experiments have shown that fluctuations in magnetic field intensity shorten the lifespan of rats, increase the human flicker-fusion threshold, and affect the orientation of unicellular algae, higher plants, insects, mollusks, fish, and birds. Such fluctuations also affect the general health of people, as reflected in hospital statistics. Increased magnetic field intensity stimulates motor activity, decreases sensitivity to some stimuli, and affects EEG activity. Conditioned reflexes to a magnetic